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Decision Support System for Sunscreen Selection Based on Facial Skin Concerns Using the Analytic Network Process

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ABSTRACT

Exposure to ultraviolet (UV) radiation is one of the primary causes of premature skin aging and various facial skin problems. However, selecting an appropriate sunscreen product remains challenging due to limited consumer knowledge and the overlapping nature of facial skin concerns. This study proposes a decision support model using the Analytic Network Process (ANP) to determine the most suitable sunscreen product based on six common skin problems: acne-prone skin, very dry skin, outdoor-induced dullness, aging, hyperpigmentation and acne scars, and general dullness. These criteria were derived from literature and validated by a certified skincare expert. Nine sunscreen alternatives from the Wardah brand—chosen due to their wide usage in the Indonesian market and varying SPF, PA levels, and formulations—were evaluated. Expert judgment was used in pairwise comparisons, with Consistency Ratio (CR) used to ensure reliability. The ANP model was developed using unweighted, weighted, and limit supermatrices. Results showed that Wardah UV Shield Aqua Fresh Sunscreen Serum SPF 50 PA++++ had the highest global priority score. A prototype web-based system was built using PHP and MySQL to deliver personalized sunscreen recommendations. The novelty of this study lies in its integration of expert dermatological insights and the use of ANP to address interrelated skin concerns, which are rarely explored in prior skincare decision support research.

I. INTRODUCTION

Exposure to ultraviolet (UV) radiation is a major contributor to various skin issues such as premature aging, pigmentation disorders, and inflammation. Studies estimate that approximately 80% of premature aging cases are directly caused by UV exposure [1]. While sunscreen serves as a primary defense against UV rays, many consumers struggle to choose the right product due to a lack of understanding of key factors such as SPF and PA levels, active ingredients, skin compatibility, and formulation types [2][3].

This lack of awareness often leads to the selection of unsuitable products, potentially causing irritation, acne, or excessive dryness. Different facial skin problems such as acne-prone skin, very dry skin, outdoor-induced dullness, aging, hyperpigmentation, and general dullness require tailored protection strategies [4][5][6]. Furthermore, sunscreens come in various forms—chemical, physical, and hybrid—each with specific benefits depending on the user's skin condition [7]. Without structured decision-making support, most consumers rely on subjective trial-and-error approaches that are inefficient and may not lead to optimal results.

Several decision-making models have been used in skincare selection, including Simple Additive Weighting (SAW) and Analytic Hierarchy Process (AHP) [8][9][10]. However, these models assume a linear or hierarchical relationship among criteria, which does not capture the complexity of real-world skin issues. In practice, skin concerns often overlap—acne-prone skin can also be dry, and signs of aging may co-occur with pigmentation or dullness.

To address these interdependencies, the Analytic Network Process (ANP) was introduced as a generalization of AHP. ANP allows for feedback loops and inner dependencies between criteria, making it well-suited for complex, multi-criteria decision-making problems such as personalized

skincare recommendations [11][12]. Previous studies have demonstrated the effectiveness of ANP in various domains such as healthcare [13], logistics, and smart technology, but its application in skincare remains limited [14].

This study aims to fill that gap by implementing ANP to evaluate nine sunscreen products from the Wardah brand based on six common facial skin problems. Expert judgment from a professional beauty advisor was used for pairwise comparisons, and the model was implemented into a web-based decision support system (DSS). The primary contribution of this research lies in demonstrating how ANP can enhance the sunscreen selection process by providing personalized, structured recommendations tailored to individual skin concerns.

The novelty of this study lies in integrating ANP with expert knowledge of dermatological skin concerns to guide sunscreen selection—an approach that is still rare in skincare decision support research [15] [16]. This integration addresses overlapping skin issues through structured pairwise prioritization, offering a more robust recommendation system compared to conventional linear models.

II. METHODS

This research employs a quantitative approach using the Analytic Network Process (ANP) method to determine the most suitable sunscreen product based on common facial skin problems. ANP allows for feedback and interdependence among decision elements, making it appropriate for complex consumer product evaluations such as skincare [11].

A. Criteria and Alternatives

Six facial skin problems were used as the decision criteria: acne-prone skin, very dry skin, outdoor-induced dullness, aging, hyperpigmentation and acne scars, and general dullness. These skin problems were identified through a literature review [4][5] and validated by a skincare expert during the early stage of system development.

As decision alternatives, nine sunscreen products from the Wardah brand were selected. Wardah was chosen due to its popularity in the Indonesian skincare market and its wide variety of sunscreen types. Products were selected based on their SPF/PA rating, texture, target skin problem, and formulation type. Table 1 presents the complete description of the selected products.

TABLE I
LIST OF WARDAH SUNSCREEN ALTERNATIVES

Code	Product Name	Figure
A1	Wardah UV Shield Essential Gel Sunscreen Serum SPF 35 PA+++	
A2	Wardah UV Shield Aqua Fresh Sunscreen Serum SPF 50 PA++++	
A3	Wardah UV Shield Light Matte Sun Stick SPF 50 PA++++	
A4	Wardah UV Shield Active Protection Serum SPF 50 PA++++	
A5	Wardah UV Shield Airy Smooth Sunscreen Serum SPF 50 PA++++	
A6	Wardah UV Shield Acne Calming Sunscreen Serum SPF 50 PA++++	
A7	Wardah UV Shield Acne Calming Sunscreen Moisturizer SPF 35 PA+++	
A8	Wardah UV Shield Physical Sunscreen Serum SPF 50 PA++++	
A9	Wardah UV Shield Tone Up Sunscreen SPF 50 PA++++	

B. Expert Involvement and Data Collection

A structured interview and observation were conducted with Sheilla Syafira, a certified beauty advisor with over seven years of experience in providing skincare consultations. She was chosen as the domain expert to perform pairwise comparisons and validate the model. The Saaty scale (1–9)

was used to construct comparison matrices for both criteria and alternatives [11].

C. ANP Network Structure and Processing

The ANP network consists of three clusters: the Goal (selecting the best sunscreen), Criteria (six skin problems), and Alternatives (nine sunscreen products). Interrelationships among criteria are considered, as some skin problems may co-occur. The model's network structure is shown in Figure 1.

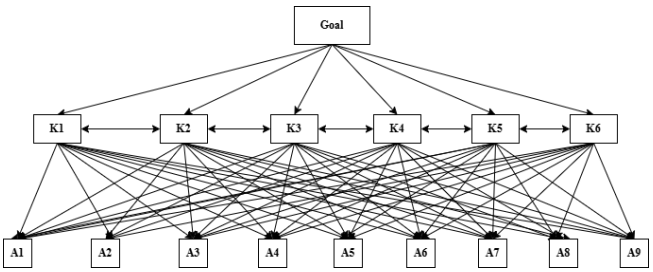

Figure 1. Network Structure

Each comparison matrix was normalized and its eigenvector calculated to obtain local priority weights. A Consistency Ratio (CR) was computed for each matrix, with values < 0.1 considered acceptable. These weights were then used to build the unweighted supermatrix, which was transformed into a weighted supermatrix based on cluster weights. The final limit supermatrix was obtained through iterative powering until convergence was achieved.

All calculations were conducted using Microsoft Excel, and the decision model was integrated into a web-based interface developed with PHP and MySQL for real-time recommendation.

III. RESULT AND DISCUSSION

A. Global Priority Results from ANP

Following the ANP methodology, pairwise comparison matrices were developed for both criteria and alternatives. Each matrix was normalized and evaluated for consistency using the Consistency Ratio (CR), and all matrices yielded CR values below 0.1, indicating consistent expert judgment (Saaty, 2001). After eight iterations of matrix powering, the final limit supermatrix was achieved, indicating convergence.

The global priority weights of the nine sunscreen alternatives are shown in Table 2. These scores represent the relative effectiveness of each product in addressing the six facial skin problems assessed in this study.

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TABLE II
GLOBAL PRIORITY SCORE OF SUNSCREEN ALTERNATIVES

Alternative	Sunscreen Product	Global Weight	Rank
A1	Wardah UV Shield Essential Gel Sunscreen Serum SPF 35 PA+++	0,000325507	2
A2	Wardah UV Shield Aqua Fresh Sunscreen Serum SPF 50 PA++++	0,000384847	1
A3	Wardah UV Shield Light Matte Sun Stick SPF 50 PA++++	0,000143083	7
A4	Wardah UV Shield Active Protection Serum SPF 50 PA++++	0,000137554	8
A5	Wardah UV Shield Airy Smooth Sunscreen Serum SPF 50 PA++++	0,000199536	5
A6	Wardah UV Shield Acne Calming Sunscreen Serum SPF 50 PA++++	0,000104893	9
A7	Wardah UV Shield Acne Calming Sunscreen Moisturizer SPF 35 PA+++	0,000145316	6
A8	Wardah UV Shield Physical Sunscreen Serum SPF 50 PA++++	0,000250113	4
A9	Wardah UV Shield Tone Up Sunscreen SPF 50 PA++++	0,000262276	3

Wardah UV Shield Aqua Fresh Sunscreen Serum (A2) achieved the highest global weight, making it the most suitable sunscreen across the combined criteria.

B. Analysis and Interpretation

The top-ranked sunscreen, Wardah UV Shield Aqua Fresh SPF 50 PA++++, is a water-based formulation with Aqua Ceramide technology. It offers high UV protection while providing hydration, which makes it suitable for individuals with dry and combination skin types. Its lightweight consistency contributes to its high ranking.

The second-highest product, Essential Gel SPF 35, though it has lower SPF, features a non-comedogenic gel texture, making it favorable for sensitive and acne-prone skin. The product balances protection and gentleness, which aligns with expert judgments.

Products such as Tone Up Sunscreen (rank 3) and Physical Sunscreen (rank 4) offer added cosmetic or mineral-based advantages, contributing to their prioritization. On the contrary, the Acne Calming Sunscreen Serum ranked lowest, possibly due to fewer multifunctional properties or thicker texture that may not be ideal for broader skin concerns.

C. Discussion in Relation to Prior Research

These findings are consistent with research suggesting that skincare product effectiveness depends not only on SPF levels but also on ingredient formulation and skin compatibility (Zhang et al., 2018; Kusumaningrum et al., 2023). The use of ANP enhances decision-making by accounting for interdependencies between skin concerns, which traditional AHP approaches often overlook (Saaty, 2001).

Expert judgment in this study was provided by a beauty advisor with more than seven years of experience in skincare consultations, which adds domain relevance. The global weights calculated using ANP allowed for a comprehensive ranking of products that considered multiple skin concerns simultaneously. Figure 2 presents the bar chart visualization of product scores.

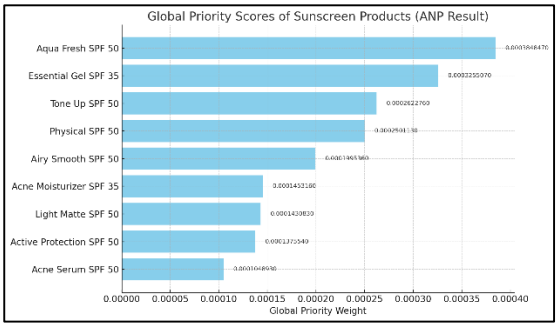

Figure 2 Bar Chart of Global Priority Scores

D. Study Limitations and Future Work

Although the ANP-based model offers structured product rankings, this study has several limitations. First, the system has not yet been tested with end-users or dermatologists to validate recommendation relevance or user satisfaction. Second, no sensitivity analysis was performed to assess how changes in comparison weights may influence the final ranking.

Future research is encouraged to conduct usability tests and incorporate robustness analysis to improve the decision support model.

E. System Implementation

A prototype web-based system was developed to implement the ANP decision-making model using PHP and MySQL. The system allows users to input their skin problems and receive real-time recommendations based on the final priority scores. Figure 3 shows the interface used to collect user inputs before running the ANP-based computation and recommendation.

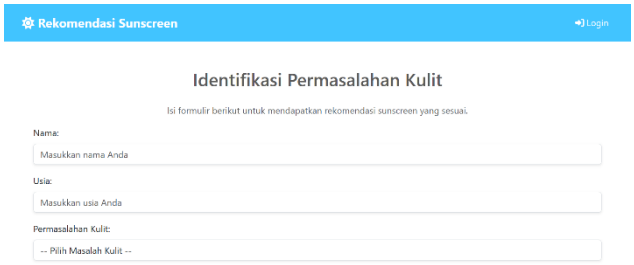

Figure 3 User Input Form in the Sunscreen Recommendation System

IV. Conclusion

This study has successfully implemented the Analytic Network Process (ANP) method to determine the most suitable sunscreen product based on multiple facial skin problems. The ANP model considered six major skin concerns and nine alternative sunscreen products. The process involved pairwise comparisons from a domain expert, normalization, consistency checking, and super matrix construction until convergence was achieved in the limit super matrix.

The results show that Wardah UV Shield Aqua Fresh Sunscreen Serum SPF 50 PA++++ achieved the highest global priority score, making it the top recommended product. This demonstrates the potential of ANP as a decision support tool in the skincare domain, especially when interrelated criteria must be considered.

A prototype web-based system was developed to implement the ANP logic in an interactive manner, allowing users to input their concerns and receive personalized sunscreen recommendations. While the system is functional, it has not yet been tested by users or validated through dermatological studies.

Future research is encouraged to perform sensitivity analysis and conduct user acceptance testing to enhance system reliability and scientific validation.

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